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INFLUENCE OF ORCHARD SOIL MANAGEMENT ON THE FORMATION AND DEVELOPMENT OF APPLE BUDS

By

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Introduction.

The chief object of all our endeavors in orcharding is the production of the largest possible amount of high class fruit, and since the fruit must be developed from the flower the importance of the flower formation and proper development is apparent.

Many experimenters have worked on the development of the flower and numerous experiments have shown that different methods of soil management have a decided effect on the growth and production of fruit trees. If by a careful study of the flower formation it would be possible to determine the effect of the different systems of management on tree growth and its relation to flower formation and fruit development, bud study would have accomplished one of its main objects. Again it is known that the inherent character of bearing fruit trees varies in degree with the different varieties, and also with individuals within a variety and even goes so far as to vary much with different parts of the same tree. If this individual variation were true would not the determination of these factors be of help as guides to orchard practice and to the propagator who believes in pedigreed scions.

The study of buds requires a thorough understanding of the morphology of flower development. Then the study of bud formation is so comprehensive, and the time required for microscopic examination of such length, that only a few of the above

mentioned phases have been taken up in this paper, which should be classed as a preliminary report.

Statement of Problem

The problem was to study whether different kinds of soil management show appreciable differences in the formation and development of apple buds. The investigation had to do mainly with the following points.

1. The determination of the dates of leaf and fruit bud differentiation and dates at which certain stages were reached in the development of the flower bud, such as differentiation of the flowers in the bud, origin of the calyx primordium, origin of the corolla and stamen primordia, origin of the carpel primordium, origin of the sporogonous tissue in the anthers with the date of reduction division and subsequent formation of the pollen and date and duration of the blooming period.

2. How the systems of orchard management, vegetative growth, production and individuality of each tree affected the dates at which the different floral structures appeared.

The work was started on July 5, 1916 and buds were collected at definite intervals from two varieties of six trees each; Grimes Golden and Jonathan, which are located in the State Experiment Orchard at Council Bluffs, Iowa. These

trees represent plots under four different orchard management conditions, namely, white sweet clover sod, cover crop, blue grass sod, and clean tillage with two trees of each variety serving as checks in the first two named conditions.

Each collection of buds consisted of ten from each tree or one hundred and twenty in all. The buds were imbedded in paraffin in the usual way and sectioned with the microtome. After some practice in technique the sections could be made thin enough to trace the development of the buds in detail. The stages of growth were recorded by measurements and drawings.

Methods

As a thorough knowledge of the minute bud parts can only be gained by a microscopic examination, it seemed best to make permanent slides of each stage in the development of the flower. Since this work consumed a large part of the time devoted to the investigation, a few of the principle points of the method employed are given below.

Collection of buds

About four years ago T. J. Maney who inaugurated this line of investigation and later Professor F. M. Harrington who continued it, selected from each of six plots one tree each of the two varieties Grimes Golden and Jonathan, that

best represented the average growth and production of the trees of the respective plats.

When the writer took up this investigation it was thought that some check might be kept on work of the different years and therefore the same trees selected by Maney were used from which to collect the buds.

To eliminate as much chance of error as possible all buds were collected from old spurs that produced no flowers in 1916. Also since the stage of development of the flowers in a cluster varies with position the terminal flower of the cluster was used during the whole experiment as a basis of comparison.

Beginning with July 6, 1916 the first collection of material was made and consisted of ten buds from each of the twelve trees.

During the following forty-two weeks, nineteen similar collections were made at intervals averaging two weeks during the periods of active growth of the summer, fall and spring while the collections during the winter or inactive period varied from two to four weeks.

As soon as the buds were removed from the trees they were placed in labeled vials and immediately sent to the laboratory where all of the cutinized scales were removed, leaving only the vital parts of the bud and a very short peduncle to be killed.

Killing and Fixing

These important processes have for their object to suddenly terminate the life processes, and secondly to harden and fix the cells and hold them in their natural condition.

Of the various reagents tried a modification of Drinkard's (8) formula for Gilson's mixture gave the best results and was used throughout. The modification consisted of increasing the alcohol content from ten to twenty-five percent to facilitate penetration through the pubescent parts of the flower.

The material was left in this reagent from ten to twenty hours according to the stage of development of the flower.

Dehydrating or the removal of all traces of water from the tissue was accomplished by means of increasing strengths of alcoholic solutions. Two hours was taken as the minimum time allowed for the material to remain in each solution.

In the 50%, 60%, and 75% alcohols iodine was added to help in the removal of the mercury from the flower tissue, while the 85% and 95% alcohols contained 10% of glycerine in which the buds were left for 24 hours to toughen the tissues and prevent brittleness, after which they were removed to absolute alcohol.

Next the material was removed from absolute alcohol and run two hours in each of six solutions of xylol of from 15%

to 100% which cleared the tissues and also prepared them for infiltration with paraffin.

The last two sets of buds were run through 25%, 50%, 75% and 100% solutions of cedar oil for clearing with the result that the material was not nearly so brittle as that cleared in xylol and could therefore be sectioned much thinner. This is an important point when running up material where thin sections are desired, for the study of heterotypic mitosis.

Infiltrating and Imbedding.

It was found best to very gradually infiltrate the flower tissue with soft paraffin which was later replaced with medium and then hard paraffin (56° - 58° C.)

The best results were obtained by imbedding the material in blocks of paraffin which were composed of four parts Leitz best grade of hard paraffin and one part Parowax. This mixture gave a grade of paraffin with a melting point of 55° C, and with a toughness that the hard paraffin alone did not afford,

During the 8-10 hours that the material was in the oven the temperature of the paraffin oven was not allowed to rise over three degrees above the melting point of the paraffin used. This was very important because if temperature became higher than three degrees above the melting point of the paraffin the tissue of the buds became hardened and brittle and could not be sectioned.

Sectioning.

By being very careful in running up the material it was found possible to get good sections from buds taken at any time during the year when imbedded in paraffin and the last results indicate that with a little more experience and caution all of the buds of this experiment could have been sectioned on the rotary microtome which would have saved an immense amount of time and allowed many more buds to have been sectioned.

Between July and October all buds were cut on the rotary microtome, the sections being from 10-15μ thick. All buds taken between October and the middle of January were so hard that better results were obtained with the slow working sliding microtime, cutting sections from 15-25μ. On January 15th a new oven was installed in the laboratory over which a better control of temperature could be kept with the result that the remainder of the buds cut perfectly on the rotary microtome.

The sections cleared in cedar oil cut nicely and could be cut as thin as 8μ.

Staining

In general all but the last two sets were stained with Delafield's Haematoxylin according to the procedure recommended by Chamberlin (6). It was found that ten minutes staining gave the tissue a heavy overstain which gave excellent differentiation to the different flower tissues when destained in 70% acid alcohol. In the last two sets the

iron alum haematoxylon facilitated the study of mitosis which was taking place at that time.

Over a thousand slides were made which contained only the longitudinal median sections of almost as many terminal flowers of the bud cluster or cyme.

Review of Literature

The investigations here mentioned have been selected from the large field on bud formation. In this review only those investigators have been mentioned who have worked on the factors influencing apple bud development.

1884.

Vincent (33) made a careful set of notes on the development of the spring condition of fruit buds, March 6 to July 24, 1884, of several of the common orchard fruits. In the apple a table of measurements of the different flower parts at blossoming time is well worked out and it was found that for a distance of one-fourth inch below the bud all starch was changed to sugar.

Goff must be given the credit for being the first to make a systematic study of the origin and development of apple flowers. In 1898 (10) the investigations on the Hoadley Apple showed the first evidence of flower and leaf bud differentiation starting on June 30th.

As a result of the second investigation, Goff (11) draws the following conclusion. Embryo flowers may form in September as well as July and suggests that flowers are formed as a result of a check in growth which may be caused

by drough in summer or the cool nights of autumn. Also that the flower buds are not structurally different from leaf buds but that they probably never revert back to leaf buds.

The results of the third seasons investigations (12) were summarized by the statement that embryo flowers may form on any tree from the time vegetative growth ceases till the middle of September.

1909 - 1910

Drinkard (8) worked out in detail the development of three varieties of apples under Virginia conditions. The following facts were determined about the Duchess apple. The date of leaf and flower bud differentiation was as early as June 20th. This was immediately followed by a period of active growth with conspicuous calyx and stamen primordia existing by July 7th and flower parts practically complete by the first of November. In the following spring pollen grains were completely formed and the flowers were ready to open by April first. In conclusion the following statement is made, "The proper development of the fruit bud would therefore be influenced by factors which are brought to bear upon the tree prior to and during the period at which fruit-bud formation takes place. In the practice of such orchard

operations as are designed to influence or control fruit-bud formation, it appears that such operations should be more effective in the spring and early summer than at other stages of development.

To further prove the last statement in 1913 and 1915 Drinkard (9) conducted experiments to determine the effects of pruning, ringing and stripping on the formation of fruit buds on the dwarf apple trees. The results indicate that spring pruning at the time of growth resumption retards the formation of fruit buds, while summer pruning the last of June greatly stimulated the formation of fruit buds. Fall pruning in November had little effect on bud formation. Stripping in June acted the same as pruning at that time. Ringing also stimulated bud formation when done after the leaves matured.

1911.

Remy (29) conducted a study of the relations existing between fertilizers applied to fruit trees and the nutritive content of the various organs of the tree. One row of trees received a complete fertilizer. In the other rows nitrogen, potash, phosphoric acid, and lime, respectively were withheld.

The results are as follows:

"Observations indicate that a certain amount of nitrogen

is necessary for the abundant development of fruit buds."

"The ratios between the various nutritive elements appear to exert some influence on fruit-bud development although this influence can not be shown."

Pickett investigated the effect of soil management on fruit bud formation of the Baldwin apple. The results of the first paper (27) which were largely drawn from macroscopic study indicate that clean tillage induces the formation of many more fruit buds than sod culture. The two most important factors stimulating fruit bud production were, moisture and nitrogen added to the soil in the form of a cover crop.

In the second paper (28) the factors influencing fruit bud formation are reviewed with their relation to the life of the tree and its production. Moisture and its relation to food making and bud formation. Nitrogen and its relation to pruning. Spraying and the influence of the stock on the scion. In the last case it is claimed that a tree grafted on Paradise stock will produce flowers a couple of years earlier.

1913

Kraus (20) in his work on the morphology of the apple worked out the development of the different flower parts.

In (21) 1915 in his study on fruit buds he explains the ways in which flower buds may be borne. He then explains the relation of pruning to flower and fruit production.

1915

Bradford (4) conducted investigations to determine the relation between development and position on the tree of yellow Newtown buds with the following results. Fruit buds borne on spurs differentiate earlier than those on sprigs. The buds of old spurs that did not produce flowers the current year showed the most uniformity of any group, while on those that produced flowers whether they set fruit or not the buds showed great differentiation in development.

A short consideration of variation of varieties was undertaken with the result that a wide range of development was found due to variety and individual factors.

Gourley (14) made a list of the important factors claimed to have influenced fruit bud formation. He discussed the tree responses to cultural treatments as found in Picketts work.

1916.

Magness (24) conducted an extensive experiment to determine the influence of summer pruning upon bud development under Oregon conditions which brought out the following facts. Axillary leaf and fruit buds became differentiated one month later than spur buds on the same tree.

Early summer heading back had no influence on the number of fruit buds on spurs, but reduced the number of fruit buds formed on the one year wood.

Black (3) conducted two years experiments on the development of the Baldwin apple from the incipient shoot to the subsequent formation of the fruit. This investigation throws light on apple development as never before, besides bringing out the following facts. The fruit buds of the Baldwin apple cannot be distinguished by their size and the bud scales are modified petioles. The so called pome fruit of the apple may be considered a reenforced or composite fruit consisting of one to several drupe-like fruits embeeded in a fleshy torus.

The State Experiment Orchard

Professor S. A. Beach in 1903 at the New York Experiment Station inaugurated the ten year experiment, with the object of comparing tillage and cover crop methods with the sod method of soil management for apple orchards. The results of this experiment were finally reported by Hedrick (17) in Bul. 314 (1909), 375 (1914) and 376 (1914) of that station.

In 1910 Professor Beach took the initiative in establishing a similar line of experiments by the Pomology and the Soils Sections of the Iowa Experiment Station. This work is being carried forward as a fifteen year project in the State Experiment Orchard at Council Bluffs, under the immediate management of Laurenz Greene, Chief of the Pomology Section.

The material basis of the writers investigations were supplied by this orchard. The writer is under special obligation to Professor Greene, for opportunity to secure the buds for this investigation and for supplying with the unpublished data from the Experiment records of the trees from which the buds were taken.

At the time the orchard was leased it was eighteen or nineteen years old, and it was perhaps in a little better condition than the ordinary neglected orchard of similar size and age. The soil of this orchard is known as a Missouri Loess. It has a texture almost as fine as clay

but is very porous and affords excellent drainage. This soil is very deep and on account of being retentive of moisture is an ideal orchard soil.

The part of the orchard included in the experiment was divided into six plots. These have received the following treatment since 1910.

Plot One - Clover Sod

This plot has an east slope. In 1910 it was seeded to red clover but a ppor stand resulted, and in the spring of 1914 white sweet clover was seeded in this plot. A very heavy stand was obtained in 1915 but the clover failed to reseed itself and in 1916 the plot was covered with weeds.

Plot Two - Cover Crop

This plot is situated above plot one on the same east slope. Each year it receives weekly cultivations between May first and the last of July. Between July 25, and August 3rd, a leguminous or non-leguminous cover crop is sown. The two types alternate with the leguminous type, being sown on the even year. In 1915 rape and buckwheat were sown while in 1916 vetch was substituted for the buckwheat.

Plot Three - Clean Tillage

The part of plot on which the examined trees were located was near the top of the ridge on a southwest slope.

Each week from early spring till late July this plot

received each year a weekly cultivation.

Plot Four - Blue Grass

The trees from which the buds were studied were located in this plot on a southwest slope.

This plot is covered with Blue grass sod which is mowed and the grass allowed to remain on the soil as a mulch.

Plot Five - Cover Crop

Plot five is a check to plot two except that it has a southwest slope.

Plot Six - Clover Sod

Plot six is a check to plot one.

Apple Description.

Jonathan and Grimes Golden both belong to the species Malus sylvestries, M. (Pyrus Malus, L) or the common cultivated apple that was originally introduced from the old world.

In the Apples of New York Beach (1) describes the Jonathan and Grimes Golden apples. The following points are selected from these descriptions.

Jonathan, originated as a seedling of the Esopus Spitzenburg, on the farm of Mr. P. Rick of Woodstock, Ulster County, New York. Judge J. Buel described the apple in 1826. The tree is of medium size, a moderate grower, demands a fertile soil that is well drained.

Grimes Golden. This apple originated in West Virginia and its fruit was sold in New Orleans as early as 1804. The tree is moderately vigorous, with short, stout, crooked branches. Under this experiment the Jonathan was considered as the hardier variety. The Jonathan bearing most of its fruit near the ends of the branches while the Grimes Golden bore its fruit nearer the main branches.

Butler (5) divides the fruit branches into four classes as follows.

"A fruit branch is a leader in which the terminal and axillary buds in the upper two thirds or thereabouts of its length become flower buds during the season of its development."

The sprig is a shoot about a foot in length developing from two year old wood. The sprig not infrequently produces a flower bud the year of its formation. The dart is a very short spine-like branch with smooth bark. In some cases it may produce a terminal flower bud the first year but normally it does not produce flowers till the end of three years.

"The spur is a short, thick brittle branch with much wrinkled bark and breaking readily with a smooth facture. The spur usually develops from a bud formed during the previous season, that is from two year old wood, and requires two season's growth to form a flower bud."

Results

Investigators have accredited a large number of factors, with influencing flower formation. Gourley (14) found after an exhaustive study of the different factors that as many as twenty-five were of special importance.

The present investigation was limited to a very small number of factors to enable the effects of the cultural methods to be definitely determined.

The limiting of the factors was attempted by selecting only two varieties from a small orchard in which the trees were under the same climatic conditions. The trees were of the same age. Each tree received a light summer pruning in June. As far as possible all buds were selected from the same type of fruiting wood, which were old spurs that had no flowers in 1916. When this experiment was outlined, it was planned to compare the results of 1916-17 with material taken two and three years ago and therefore the same trees were under observation. These trees had been selected as plot representatives in growth and production some three years ago. Later it was found that the average had so materially changed that most of the trees now were far from average. Therefore all the results of this investigation must be considered as applying only to the individual trees and not the plots.

Two important facts which should be remembered in the following discussions are : First it is impossible to watch the development of one bud throughout the year as each time a bud is removed for study it can only tell its story till the date of its removal and it would only be a chance if we at a later date collect a bud that would have been at the same stage of development on the previous date. Therefore the results must vary between the limits of variation as found on the spurs of the same tree. Secondly - From the first few collections taken only a very small percent of buds showed differentiation between leaf and flower buds because a large percentage had not started to form flowers at that time and therefore the stage of development of those first flower buds can't be taken as the average for that tree on that date.

After making a detailed study of the 1000 slides it was found that some method of rapid comparison was essential. So two hundred camera licida drawings (x60) were made. These drawings represented the important steps in the development of the buds and make it possible for one to have various stages of development under observation at the same time. The stages of development were found to check with the descriptions of Bradford (4) and Kraus (20).

Later it was found much easier and more accurate to

make comparisons from tables which contained measurements that were indicative of the stages of each of the slides. All measurements were recorded in .01 M.M. with the unit as 10 microns.

The work of measuring brought out an interesting point which was as follows: The width of the leaf bud crown until leaf and flower bud differentiation was less than .14 M.M. This width had increased to about .27 M.M. by the time the individual flowers started to form. The width of the terminal flower increased from .16 to .24 M.M. between the time of its appearance and the first sign of the calyx primordia. From the time of the first sign of the appearance of the calyx primordia until the corolla primordia appeared, the calyx primordia increased to a height of.11 M.M. and the width of the receptacle at the base of the calyx primordia had increased from .24 to .34 M.M.

During the period of time that the receptacle was increasing in width from .34 to .50 M.M. the primordia of the corolla and stamens had appeared and attained a height of .10 M.M. At this point the carpel primordia appeared which ferentiated in the upper anthers when the carpels had reached a height of .19 to .24 M.M.

From this it would seem that during the first six months of flower development there is no difference in the size of the flowers of the two varieties, also that both varieties show a direct relation between the size of the flower parts and the stage of development.

Four tables 1 to 4 are included to show the stage of development for the flowers of each tree on some of the important dates.

Table I

JONATHAN

	Clover - Sod 1				6				Cover - Crop 2				5				Clean Tillage 3				Blue Grass 4			
DATE	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O
July 20 1916	16		2																					
Aug. 2 1916	16	9																						
Aug. 18 1916		8	3		16 21								15 16				17				18	3		
Aug. 30 1916			6		18		1						24		6				6			2		
Sept. 15 1916			5 6			7 11			16 18					5 6			19	4				4 5		
Oct. 3 1916				11 16				2 4		4 6					4	5			4 5			5		2
Nov. 13 1916				16 22				3 16				2 6				10 16				2 13				3 19

The unit of measurement is .01 M.M. or 10 microns

I= Width of the terminal flower from the time of the differentiation of the separate flowers until the time of the start of the calyx primordia.

K=Height of calyx primordia from time of formation until the time of appearance of a corolla primordium.

C=Height of corolla from formation till time of the appearance of a carpel primordium.

O=Height of the carpel primordia above the center of the torus.

JONATHAN.

	Clover - Sod		Cover - Crop		Clean Tillage	Blue Grass
	1	6	2	5	3	4
DATE	0	0	0	0	0	0
Dec. 9 1916	22 26	13 14	10 11	14 16	 11	13 21
Jan. 11 1917	14 24	16 24	 12	12 14	12 13	17 24
Jan. 30 1917	21 28	 29	 	 21	 21	 24
Feb. 19 1917	12 27	16 24	11 21	12 22	6 20	13 20
Mar. 23 1917	40 53	24 30	27 29	34 38	19 24	36 38
April 10 1917	86 Mother Cells Lose	80 Mother Cells		134 Tetrad	72 Syna-psis	77 Mother Cells
Date of Bloom-ing	May 9-17	May 9-17	May 10-17	May 9-17	May 10-17	May 10-17

The unit of measure is .01 M.M. or 10 microns.
0= Height of the carpel primordia above the center of the torus.

GRIMES GOLDEN

	Clover - Sod								Cover - Crop								Clean Tillage				Blue Grass			
	1				6				2				5				3				4			
DATE	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O
July 20 1916					16																			
Aug. 2 1916					22	3																		
Aug. 18 1916	24				17	1			22													1 9		
Aug. 30 1916		6			23		10			7	5						21				23	10		
Sept 15 1916			4				4 10				4 6						16		6				6	
Oct. 3 1916				5			6	6												4				5
Nov. 13 1916				10 19				13 19												18				19

The unit of measurement is .01 M.M. or 10 microns

I= Width of the terminal flower from the time of the differentiation of the separate flowers until the time of the start of the calyx primordia.

K= Height of calyx primordia from time of formation until the time of appearance of a corolla primordium.

C= Height of corolla from formation till time of the appearance of a carpel primordium.

O= Height of the carpel primordia above the center of the torus.

Table IV.

GRIMES GOLDEN

	Clover - Sod		Cover - Crop		Clean Tillage	Blue Grass
	1	6	2	5	3	4
DATE	0	0	0	0	0	0
Dec. 9 1916	18	22			13	19
	19	27	19		19	27
Jan. 11 1917		18	13		19	
	22	20			21	16
Feb. 5 1917		20	14		16	
	22	21			18	21
Feb. 19 1917	16	24	21			
	22	30				24
Mar. 23 1917	21	21	30			27
	24	29				30
April 10 1917	80 Mother Cells	152 Tetrad			85 Mother Cells	63 Syna-psis
Date of Bloom-ing	May 9-16	May 9-18	May 9-18		May 9-16	May 9-16

The unit of measure is .01 M.M. or 10 microns.
0= Height of the carpel primordia above the center of the torus.

Explanation of Tables. I to IV.

The object of these tables is to show the date of the formation of the different flower parts, and the range of development in each tree.

The top figure contained in the squares indicates the state of least development found in the slides of that date. The lower figure indicates the greatest development shown by any slide of the same date.

An absence of any figures indicates that all the buds taken from that tree on that date contained only leaves.

One figure in a square indicates that the slides of that date showed only one stage of development.

A study of tables one to four brings out the following important points.

Under the conditions of this experiment it required from eight to ten months for the flowers to develop to the blooming stage.

Apple flowers have two periods of rapid growth. The first period comes after leaf and flower bud differentiation. This covers about two months, during which time the minute flower parts are formed. The second period starts about six weeks before the flowers open. During this period the flower parts increase many times in size and the final size of the individual flower is determined by its rate of growth.

That the stage of development may show a month's variation in the flowers from one tree was proven by a microscopic examination. This amount was shown in a number of cases as seen in tables I and III or with both varieties from July to Sept. A considerable amount of individual variation was noted until April when all of the flowers examined showed only a few days difference in development. It was found that the variation in an individual tree may cover more time than the variation between different trees under different conditions. This makes it almost impossible to make accurate comparisons between the different tree, unless an immense number of flower buds were sectioned at each collection.

Table V.

Individual Tree Record

Jonathan

	Clover Sod 1		Blue Grass 4		Clover Sod 6		Cover Crop 5		Clean Tillage 3		Cover Crop 2	
	G	P	G	P	G	P	G	P	G	P	G	P
Aver.	129	336	103	82	114	77	174	253	109	261	192	159
1916	.68	292	.63	13	.88	109	125	340	1.	65	163	109
1915	144	848	144	252	.94	178	233	787	225	105	25	614
1914	113	345	118	292	131	746	169	24	113	6	225	6
1913	221	297	213	87	187	45	231	140		203	269	138
1912	106	16	.81	74	.69	55	107	78			156	7
1911		238		42				149		236		76
% Flower Buds	81		51		95		92		41		26	

G= Circumference increase of the tree ininches.
p= Production of the tree in pounds.

Table VI.

Individual Tree Record

Grimes Golden.

	Clover Sod 6		Blue Grass 4		Cover Crop 2		Clover Sod 1		Clean Tillage 3		Cover Crop 5	
	G	P	G	P	G	P	G	P	G	P	G	P
Aver.	.79	204	108	368	151	523	109	389	127	443	109	270
1916	.50	84	.81	324	150	793	.81	374	.75	579	125	451
1915	.44		.50	483	.69	590		270	113	592	.75	29
1914	106	640	113	469	162	806		671	106	687	125	664
1913	119	54		383	175	466		416	181	359	150	207
1912		419		484	138	402		556	125	409	.69	289
1911		48		68		60		52		36		
% Flower Buds	100.		72.		38.		92.		20.			

G= Circumference increase of tree in inches.
P= Production of tree in pounds.

The formation of sporogonous tissue began about November 13th and continued until February 19, 1917.

The order of the formation in the different trees was as follows:

Grimes Golden, blue grass sod
Jonathan, " " "
Grimes Golden, clover sod, plot six.
Jonathan, " " " one.
Grimes Golden, " " " "
" " Clean tillage
" " cover crop, plot two.
Jonathan, clover sod, " six.
" cover crop " five.
" clean tillage " three.
" cover crop " two.

From tables V and VI it is noted that the Jonathan tree with the smallest growth formed the first sporogonous tissue among the Jonathan trees. The order of amount of growth and time of formation of the sporogonous tissue checks through out the Jonathan. In the Grimes Golden it does not check out but comes near enough so that it will be seen that there is a relation between their growth and time of formation.

The mother cells did not start to form until about April first. A very cold spring held the date of blooming till May 9 to 18th for all trees.

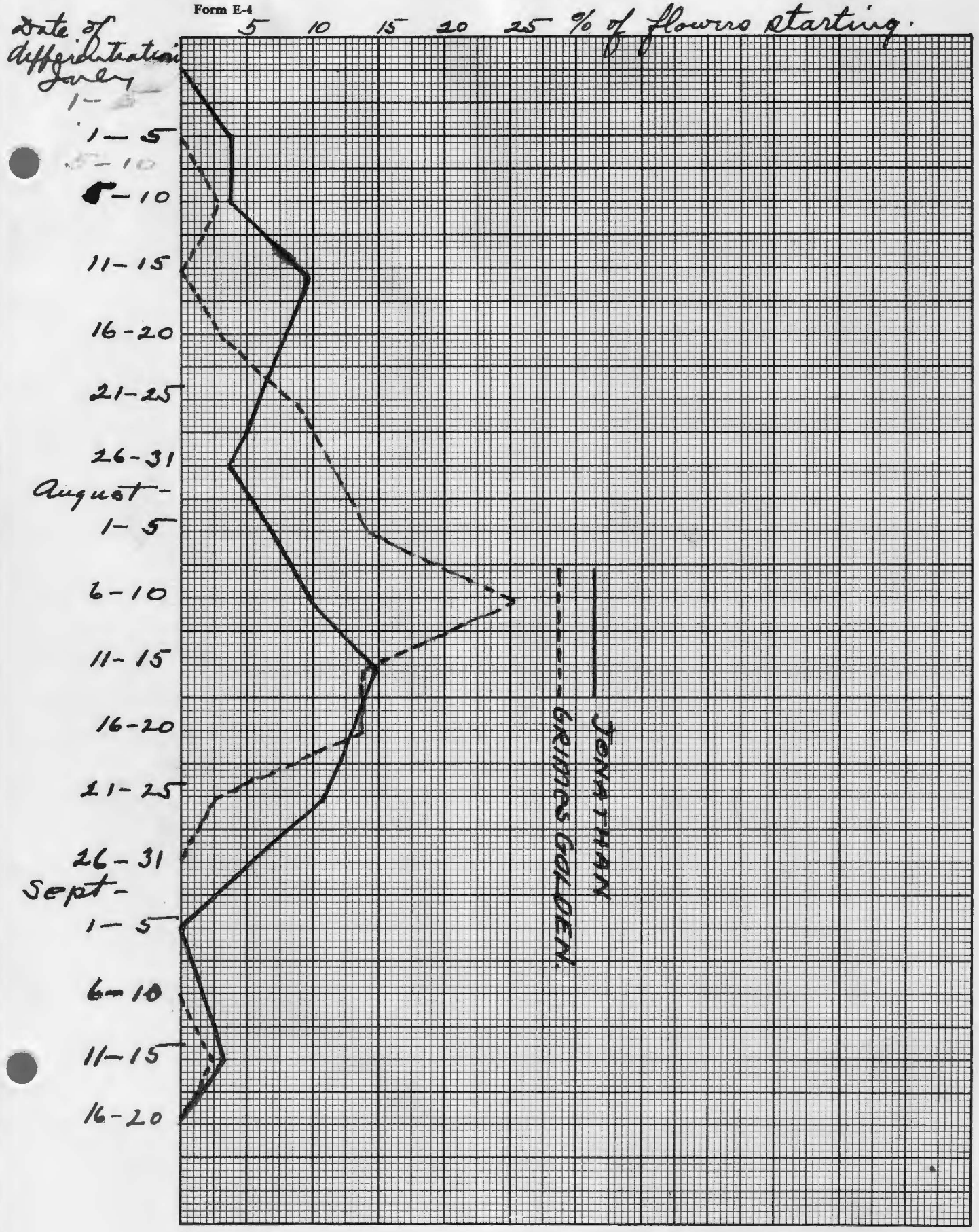
A study of the slides enabled me to approximately determine the time required by the flower in its development from one stage to another. It was found that stage I occupied a period of 8 to 16 days. Stage K occupied 10 to 16 days and stage C almost twice as long as either of the others.

From table I it is seen that the tree in plot six on clover sod had a flower on September 15th in which the calyx primordia was .07 M.M. high. To determine the date this flower started to form. Nine days would be allowed for the development of the calyx primordia of a height of .07 M.M. Then it would require fourteen days for the flower to develop through stage I, allowing two days for the elongation of the crown. It may be said that it required about twenty-one days for the flower development to reach this stage. The date of leaf and flower bud differentiation or start of flower development would then be considered as August 25th. This of course is only approximate. It was possible to determine the approximate time in which each flower started to develop, by allowing a definite period of time for each stage of flower development.

By this method the time of leaf and flower bud differentiation was determined for the hundred flowers in classes I and K. These dates were embodied into the curve of table VII. Table VII while allowing for a small error in time of

Table XII

Form E-4



formation shows the following important points.

At a glance the percent of flowers that started to form between certain dates may be determined for either variety.

The curve for each variety shows three crests, which indicate three periods of flower formation. The first period came about July 10 to 15th. This period included the dates on which flowers started to form on trees grown in the sod plots. This crest was called the abnormal.

The second period of flower formation occured August 6 to 15th. This period included the dates on which flowers started to form on trees in the cultivated plots, and certain trees in the sod plots where the water content of the soil was found to be as high as in the cultivated plots. The period of flower formation is called the normal period.

The third period was very brief, beginning on the tenth and ending on the fifteenth of September. Half of the dates of flower formation of this period were ascertained from the buds of one tree in the clover sod plot where the water content of the soil was much higher than the other plots.

From a further study of the tables I to IV it was noted that the formation of flowers for the two varieties of trees took place in the various plots in the order as shown below.

Jonathan	Grimes Golden
1. Clover sod.	1. Clover sod.
2. Blue grass sod.	2. Blue grass sod.
3. Clover sod.	3. Cover crop.
4. Cover crop.	4. Clover sod.
5. Clean tillage.	5. Clean tillage.
6. Cover crop.	

The factors causing flower formation may now be considered.

Jost (19) treats this as follows: "In general however, our information as to the factors which are essential to the formation of flowers is very imperfect. The facts which have been brought forward prove, however, that the periodicity in blooming usually observed is fixed once and for all but may be experimentally influenced", and "That in flower formation not merely external but also internal stimuli may play an important part". Also that "All factors which tend to advance foliage development are unfavorable to flower production and vice versa" and last that, "If it be proved for instance, that a dry soil increases flowering, and that a wet one retards it, we can only say that the character of the soil directly influences the roots and only indirectly the aerial organs". The last statement of Jost leads to the question: What is the effect of varying amounts of soil mois-

ture on the time of flower formation?

This question may be partly answered by comparing the soil moisture content taken near each of the Jonathan trees with the time of the flower formation in each tree; for when soil moisture was abundant, flower buds formed late.

The soil moisture content is shown in table VIII.

Table VIII at once indicates that there may be some relation between flower formation and water content. If the last statement quoted from Jost is here assumed true for the purpose of finding if a relation exists between water content of the soil and flower formation, it must also be granted that the relation will directly influence vegetative growth and only indirectly the time of flower formation.

On July 14th the water content of the soil was found in plots one and three to be four percent lower than that of all other plots. The total water content in clover sod, plot I, was 8.15% with a subsoil water content of 8.3%, while the total water content of the blue grass plot was 8.%

Jost stated that "All factors which tend to advance foliage development are unfavorable to flower production."

The next point to be determined is the relation of foliage growth to flower formation as influenced by the soil water.

Table V shows the increase in circumference of each tree. The increase in circumference of the tree is claimed

Table VIII.

Percentage of Soil Moisture

Taken Near Jonathan Trees

	Clover Sod		Cover Crop		Clean Tillage		Blue Grass		Cover Crop		Clover Sod	
	1		2		3		4		5		6	
Date	S	SS	S	SS	S	SS	S	SS	S	SS	S	SS
June 25 1916	10.8	10.7	15.6	14.	13.5	13.2	10.6	9.6	16.1	15.1	15.7	14.7
July 14 1916	8.	8.3	16.9	16.5	15.4	16.9	7.6	8.4	15.4	13.2	13.3	12.9
July 31 1916	6.7	7.	16.5	15.4	14.3	9.3	5.6	7.	11.9	11.5	9.5	8.7
Aug. 15 1916	11.1	7.3	14.	10.8	14.5	10.6	10.5	6.5	16.1	14.8	9.4	7.2
Aver. %	9.1	8.3	15.	14.2	14.4	12.8	8.5	7.8	14.8	13.4	11.9	10.8

S= Surface soil.
SS= Subsoil.

by the Iowa Experiment Station to be an index to the twig growth. The relation between soil water content and circumference increase of the tree is shown by the following table:

Method of Soil Management	Circumference Increase of Tree in 1919 inches	Average Soil Water Content. June 25 to August 15.
Blue grass sod	.63	8.1%
Clover sod Plot 1.	.68	8.7%
Clover sod Plot 6.	.88	11.3%
Clean Tillage	1.	13.6%
Cover Crop Plot 5.	1.25	14.1%
Cover crop Plot 2.	1.63	14.6%

The above table shows a direct relation between soil water content and tree growth.

The order of the flower formation did not confirm in all cases with the total soil water content and tree growth. These results indicate that soil water content directly influences growth. Jost's statement on the effect of growth

on flower formation and Sorauer's (32) statement "That vegetative growth and flower-bud formation will not occur simultaneously" would lead to the following conclusions.

The soil water content through its direct influence on vegetative growth, under the conditions of the experiment was the principal factor in influencing the formation of the flowers.

Many other factors may have exerted some influence on the time of the flower formation. Among the most likely would be nitrogen. Remy (29) and Pickett (27) conducted experiments which indicated that nitrogen is a very important factor in stimulating the formation of flowers in the apple.

These results seem to have been borne out by the present investigation. In case of the Jonathan trees the soil water of the blue grass plot was slightly lower than that of the clover sod, plot one. The results indicate that nitrogen likely had some influence on the time of the flower formation because flowers were formed on the tree in clover sod a couple of weeks earlier than on the tree in blue grass. Again the tree in clover sod, plot six, with a higher water content of the soil than the blue grass plot tree formed flowers only a few days later than the clover sod tree.

Moisture samples were taken at varying distances from

the Grimes Golden trees but the tests in each plot showed so much variation that no accurate figures were obtained and therefore no comparison could be made.

The relation between the increase in circumference of the trees and the time of the flower formation was as follows.

The tree on clover sod, plot six, was slightly ahead of the tree on blue grass in the time of flower formation. The increase in circumference was .50 inches for the former and .81 inches for the latter. The trees in clover sod, plot one and cover crop, plot two, had their time of flower formation at the same time. The clover sod tree increased .81 inches while the increase in circumference of the tree on the cover crop plot was 1.50 inches. The tree on clean tillage was last in time of flower formation with an increase in circumference of .75 inches.

Most of the trees of both varieties showed a tendency towards alternate bearing. Any method of comparison between the production of a tree and the time of its flower formation failed to show results. This could be expected because of the many factors incluencing the crop before its maturity.

It was found that the trees under the four methods of orchard culture could be divided into two groups. The first

group to comprise those trees grown on the sod plot. The flowers of the trees of this group formed before all trees of the second group except one case where they were even.

The second group to comprise those trees grown under cultivation whose flowers did not start to form until after the formation of the flowers of group one.

From this it would seem that there must be some important factors at work. The main factor was shown to be the moisture supply, with a lack of moisture resulting in early flower formation.

Hedrick (17) reporting on experiments inaugurated by Beach states that 120 determinations on tilled land and sod showed a higher percent of moisture in the tilled land. Also that the trees on the sod with the smaller amount of soil moisture seemed amiss or not at their best. Their foliage was of a yellow color, the fruit small and maturing one to three weeks earlier than that on the trees under tillage. The trees growing in sod plots showed abnormalities in foliage, branches, roots and fruit characters.

In the orchard at Council Bluffs much the same conditions were noted for the trees growing in the blue grass sod plot.

The flower buds that were selected to be sectioned were measured during February. The result is as follows:

Buds produced on trees in blue grass sod averaged 4x6.1 M.M.

Buds produced on trees on clover sod averaged 4.4x6.9 M.M. Buds produced on trees under cultivation averaged 4.55x7.7 M.M.

All the buds taken from the trees in the sod plots were harder to section and seemingly were composed of harder tissues. The flower buds from the Jonathan tree in blue grass were excessively hard and the scales were covered with cutinized tissue instead of the usual pubescent scales as found on the cultivated plot trees.

It would seem that the trees grown in the sod plots were abnormal in most of their functions. As these trees produced buds containing the earliest formed flowers might not these flowers be abnormal? The trees in the cultivated plots formed their flowers much later and on an average produced a much larger crop than the trees on the sod plot.

From this the hypothesis is set forth that a shortage of water in the soil checks food production and plant growth. The plant is then in a weakened or abnormal condition due to a shortage of food and water which induces in the plant an effort to perpetuate the species by the formation of flowers. Now it would seem that the effect of the different methods of soil management on flower formation would be determined by their power of conserving the soil moisture during the summer months.

The sods and other methods wherein no cultivation is

given the orchard from June to the last of July tend to reduce the water content of the soil. If the trees are so situated that the moisture of the soil falls far below the average the trees are weakened vegetatively and induced to form flower buds.

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